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A COMPARISON OF TWO METHODS FOR STUDYING THE DIET OF THE PEREGRINE FALCON

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KEY WORDS: diet; *Falco peregrinus*; methodology; peregrine falcon.

A frequent difficulty in the study of raptor diets is determining how valid the results are as the result of the sampling methodology. Stomach contents, pellets, prey remains, and direct observation are the main methods applied (Marti 1987). Many studies have used just one of these methods (e.g., Bustamante 1985, Nielsen and Cade 1990, Tella 1991). Others used a combination of some of them (e.g., Restani 1991, Mañosa and Cordero 1992, Underhill-Day 1993), but biases produced by the different methods have been tested only for few species (Collopy 1983, Simmons et al. 1991, Hunt et al. 1992, Mersmann et al. 1992, Real 1991, Mañosa 1994).

The aims of this paper are (1) to compare pellet contents with uneaten prey remains in determining the diet of the peregrine falcon (*Falco peregrinus*), and (2) to develop a more accurate method to evaluate peregrines' diet by using both methods separately or in conjunction.

METHODS

The study was carried out on 7500 km^2 in the Ebro Valley, northeastern Spain (Tella 1991, 1993). Diet samples were collected from below cliffs used by 19 breeding pairs of peregrine falcons that remained in the area year-round. The collections were made between 1987 and 1993, on a regular basis throughout the year to avoid biases associated to seasonal variations in the diet (Mearns 1982, 1983). Collections were carried out by one or two people carefully searching for pellets and small remains for 45–120 min (Langvatn 1977). Each collection of prey remains and pellets from a pair on one date was considered to be a sample. Prey remains were identified using our comparison collection of bones and feathers and those from the Museum of Zoology of Barcelona. Mass of prey was estimated from the literature (Geroudet 1946–57, Cramp and Simmons 1977–83, Cramp 1985–93) and our own data from the study area.

Diet was determined separately from the number of prey items identified in pellets and from uneaten prey

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Table 1. Number of prey (N_p) and species (N_s) identified by two methods and the combination of both methods (Total). Species or families with $N_p < 10$ were grouped.

	REMAINS		PELLETS		TOTAL	
	N_p	N_s	N_p	N_s	N_p	N_s
Anseriformes	11	3	0	0	11	3
Galliformes	12	1	0	0	12	1
Columbiformes	291	5	14	1	291	5
Pteroclidiformes	25	2	0	0	25	2
Strigiformes	9	2	2	1	11	2
Apodiformes	36	2	4	1	38	2
Coraciformes	26	2	2	2	26	2
Piciformes	17	1	0	0	17	1
Sturnidae	58	2	40	1	64	2
Corvidae	45	5	1	1	46	5
Turdidae	29	3	3	2	31	3
Unidentified passerines	149	31	62	11	181	32
Unidentified birds	15	5	1	1	15	6
Lagomorpha	24	2	1	1	25	2
Unidentified mammals	5	2	4	1	9	2
Unidentified reptiles	2	1	0	0	2	1
Arthropoda	0	0	16	3	16	1
Total	754	69	150	26	820	74

remains in each sample. Additionally, the two methods were combined by considering the minimum number of prey identified from each unit sample (e.g., the number of spotless starlings [*Sturnus unicolor*] where we identified two starlings by remains and one starling by pellets would be two).

Results obtained by the analysis of pellets and remains were contrasted in different ways. We used the Margalef index (IM; Magurran 1988) to calculate species richness. However, due to the high number of identified species (N = 81), we grouped prey by ordinal taxa (except in passerines where we separated the three families most often preyed upon and the rest) for statistical purposes. Overlap of the results was expressed through the Pianka index (Pianka 1973). An exponential distribution in base two was used to group the prey by mass categories. Differences between taxa or weight distributions of prey obtained by both methods were tested with chi-square tests on contingency tables, applying the Bonferroni correction to ensure an overall $\alpha < 0.05$ when we separately compared weight intervals (Zar 1984).

RESULTS

We obtained 72 collections of prey remains and 81 pellets. Analysis showed low overlap between remains and pellet contents by taxa (Pianka's index = 0.61; Table 1). The species richness was greater in the prey remains (IM = 6.55) than in the pellets (IM = 4.42), although the lower species diversity in pellets may be due to the high number of small passerines not identified to the species level. The number of prey as well as the number of species identified in the remains (754 individuals, 69 species) was greater than that identified in the pellets (150 individuals, 26 species). The differences between these results and the totals obtained by means of the combined method (820 individuals, 71 species) were statistically significant (χ^2 = 899.21, df = 1, $P < 0.0001$ for remain analysis; χ^2 = 51.85, df = 1, $P < 0.0001$ for pellet analysis).

Results grouped by taxa (Table 1) clearly differed between remain and pellet analyses (χ^2 = 212.34, df = 16, $P < 0.0001$). Prey mass distribution also showed strong differences between the two methods (χ^2 = 172.7, df = 7, $P < 0.0001$; Fig. 1). Small prey were seldom detected in the remains. Large prey were found more often in the remains than in the pellets. Thus, pellet analysis would indicate that this peregrine population mainly consumed small- to medium-sized prey (17–128 g), while analysis of remains of the same diet would indicate a preference for the larger prey (257–512 g; Fig. 1).

DISCUSSION

Direct observations of peregrines (Dekker 1980, Bird and Aubry 1982, Thiollay 1982, Ward and Laybourne 1985) may be the best method to determine diet, but it requires a great deal of time and is often inpractical (Marti 1987). The collection of prey remains and pellets of peregrine are more practical ways to describe their diet, and they have been widely used by several authors (see review in Porter et al. 1987). Nevertheless, Mearns (1982, 1983) suggested that there were differences between the results of analyses of remains and pellets. Our results confirm these differences, and showed that the diet of the same peregrine population can offer contrasting results depending on the method used.

The absence of direct observations at nests made it difficult to evaluate which of our methods was best. None-

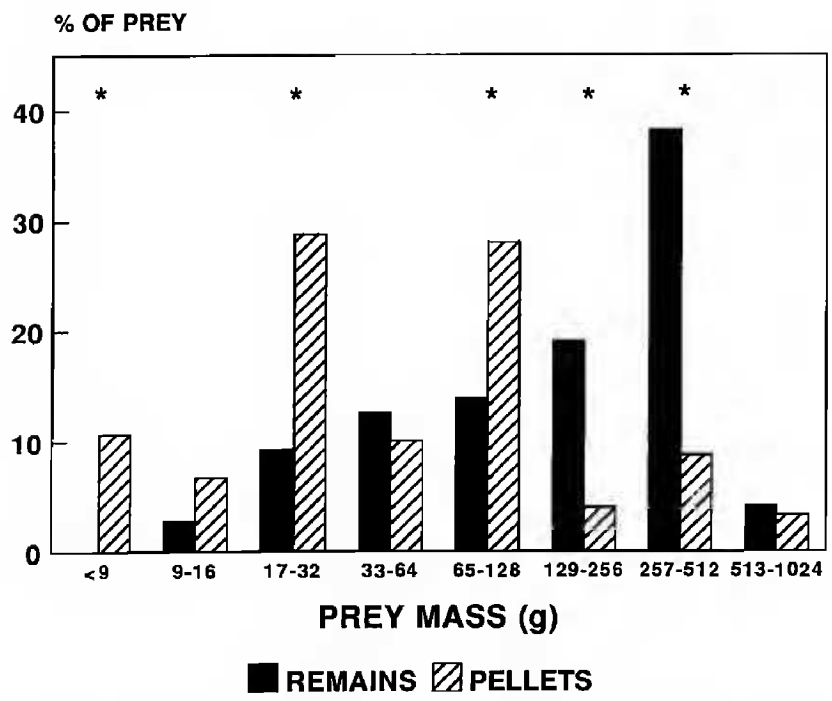

Figure 1. Mass distribution of prey identified by means of prey remains or pellet analysis. Differences were tested by χ^2 tests applying Bonferroni correction to ensure $\alpha < 0.05$. Significant differences ($P < 0.0001$) are indicated with an *.

theless, due to the very different results derived from the analysis of remains and pellets, we recommend their combined use as suggested for other birds of prey (Simmons et al. 1991, Mersmann et al. 1992, Mañosa 1994). However, small prey could still be underestimated due to the low number and low detectability of pellets, particularly under unfavorable weather conditions. In addition, the removal of large prey remains by scavengers (e.g., red fox [*Vulpes vulpes*], which often visits breeding sites of Egyptian vulture [*Neophron percnopterus*] and peregrine falcons, Tella and Torre 1990), may also reduce their detection. These biases could be avoided to a great extent by increasing the frequency of collections (e.g., Reynolds and Meslow 1984).

RESUMEN.—Hemos estudiado la dieta del halcón peregrino (*Falco peregrinus*) en el noreste de España mediante la recolección de restos de presas y el análisis de egagrópilas. Ambos métodos difieren marcadamente en sus resultados: las presas pequeñas aparecen en menor proporción entre los restos, mientras que las grandes son subestimadas en las egagrópilas. Las egagrópilas desaparecen probablemente con mayor rapidez que los restos. Recomendamos por ello el uso combinado de ambos métodos y la realización de frecuentes recolecciones, con el fin de reducir sesgos en los resultados.

[Traducción autores]

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COOPERATIVE NESTING BY A TRIO OF BALD EAGLES

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KEY WORDS: *bald eagle*; *breeding*; *California*; Haliaeetus leucocephalus; *nest helpers*.

Helpers at the nest have been reported in at least 222 bird species and are widespread taxonomically (Skutch 1961, Grimes 1976, Rowley 1976, Zahavi 1976). Although rare among raptors, helping occurs regularly at nests of the cooperatively breeding Harris' hawk (*Parabuteo unicinctus*; Mader 1975) and Galápagos hawk (*Buteo galapagoensis*; Faaborg 1986). Helpers at the nests of raptors not considered to be cooperative breeders have been reported for the peregrine falcon (*Falco peregrinus*; Spofford 1969), red-tailed hawk (*Buteo jamaicensis*; Wiley 1975), merlin (*Falco columbarius*; James and Oliphant 1986), Mississippi kite (*Ictinia mississippiensis*; Parker and Ports 1982), American kestrel (*Falco sparverius*; Wegner 1976), and Eurasian sparrowhawk (*Accipiter nisus*; Newton 1973)

Bald eagles (*Haliaeetus leucocephalus*) are monogamous and highly territorial (Stalmaster 1987). Sherrod et al. (1977) observed three adult bald eagles at two nests on Amchitka Island, Alaska, and Fraser et al. (1983) did so for a nest in Minnesota. Neither, however, presented details on the involvement of the third adult. In this paper we describe a trio of bald eagles that cooperated in territory defense, incubation and the provisioning of nestlings through fledging.

STUDY AREA AND METHODS

In 1980 a program was initiated to reestablish breeding bald eagles onto Santa Catalina Island, where the species was extirpated by the early 1960s (Garcelon 1988). The island is approximately 194 km^2 and is located 34 km southwest of Long Beach, California. Because residual DDE compounds remained in the environment (Garcelon et al. 1989), nesting attempts early in the program failed,

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